Fiber Reinforced Composites in Dentistry: A Review of Literature

Hina Abbas[1], Rabihah Alawi*[1], Nor Aidaniza Abdul Muttlib[1], Sohaib Arshad[1]

[1] School of Dental Sciences, Universiti Sains Malaysia, Health Campus,16150, Kubang Kerian, Kota Bharu, Kelantan, Malaysia

Correspondence author and reprints:

*** Rabihah Alawi**

Email: rabihah@usm.my

School of Dental Sciences,
Universiti Sains Malaysia,
Health Campus,16150,
Kubang Kerian, Kota Bharu, Kelantan
Malaysia

Abstract

Background: The enhancement of long and short fiber resins was applied in many different areas of engineering and biomedicine. The application of fiber-reinforced composites (FRCs) in dentistry was discussed and reported in the previous literature. However, there is lack of reports on the use of natural fibers in the restorative material.

Aim: The aim of this review was to revise and update the FRC and natural fibers applications in dentistry based on the reported studies and literature.

Methods: A literature search was performed using PubMed and Science Direct database to identify the related articles using multiple keywords. The keywords used were natural fibers, kenaf, fiber reinforced composite, dentistry, resin matrix and fillers. The search was limited to articles that were published in English language from the year 1982 to 2022.

Conclusion: Fiber-reinforced composite material mainly derived from synthetic fiber which has been discovered to be one of the most promising restorative materials and possess superior properties among other types of composites, dominating many applications in the most clinical applications and advanced industries. However, the use of natural fibers in dental applications is still lacking.

Key words: Natural fibers, kenaf, fiber reinforced composite, dentistry, resin matrix, fillers

Tob Regul Sci. ™ 2022;8(1): 3761-3771
DOI: doi.org/10.18001/TRS.8.1.285

Introduction

Composite resins have transformed restorative dentistry and these systems now control a substantial portion of the cosmetic and restorative materials industry. Their physico-chemical qualities have significantly improved in recent years. In clinical settings, fatigue fracture has been the most common cause of composite failure [1]. Water absorption by the resin matrix and occlusion cycle force influence composite resin fatigue on dental restorations. Fiber reinforcement has been added to these materials to improve their flexural strength and modulus. Due to the fiber-composite interface, the reinforcing component can operate as a stress concentrator in modern composites [2].

Fiber reinforced composites (FRC) are made up of a resinous matrix that holds the fibers together. They have strong flexural strength and other physical properties that are needed in restoration and even can be used as prosthesis substructure material and for tooth replacement [3]. FRC resin systems have been used in a variety of disciplines and applications, including removable prosthodontics, fixed prosthodontics, restorative dentistry, periodontology, root canal systems, orthodontics, and repairs of fixed prostheses, the invention of FRC resin systems and understanding of the designing principles behind constructing devices, as well as clinical experience. Critical examination of the available FRC materials and proper patient selection are critical for successful application of the material [4].

The concepts of FRC require greater knowledge as new technologies, nanofillers, resin matrices, fibers, adhesion processes, and application techniques, opening new avenues of research in both preclinical and clinical field. Fiber reinforced composites either consist of synthetic or natural fibers. These materials were being studied extensively and reported in the previous literature. However, the reports on the application of natural fibers in dentistry are lacking Therefore, this review aimed to revise and update the FRC and natural fibers applications in dentistry based on the reported studies and literature. The findings from this review will aid clinicians and researchers in this field to better understand and choose the suitable FRC materials in their practice. In addition, the potential use of natural fibers in dentistry will be further explored.

Methodology

A literature search was performed using PubMed and Science Direct database to identify the related articles using multiple keywords. The keywords used were natural fibers, kenaf, fiber reinforced composite, dentistry, resin matrix and fillers. The search was limited to articles that were published in English language from the year 1982 -2022. References of relevant papers were used to complete the review.

Results and Discussion

History of Dental Composites

The enhancement of long and short fiber resins was applied in many different areas of engineering and biomedicine. The application of fiber-reinforced composites (FRCs) in dentistry was discussed and reported extensively. Dentistry was no longer in the possession of barbers or artisans at the beginning of the 19th century, but it was practiced by highly minded dentists or surgeons. The term "composite" was still new to dentistry in the late 1950s and early 1960s [5]. In response to the deficiencies of silicate cements and unfilled resins (based on methyl methacrylate monomer and its polymer) composite dental filling materials were developed [6]. In the dental literature, a hybrid monomer such as "BIS-GMA" (bisphenol A diglyceryl methacrylate) was synthesized. This molecule appears like an epoxy resin except that methacrylate groups are substituted by the epoxy groups. Under oral conditions, BIS-GMA formulations can polymerize readily, and they have less polymerization shrinkage than methyl methacrylate [7]. In the time frame of their dental composite growth, approximately three major periods can be characterized: (1) mid-1960's-late 1970's with significant changes in curing characteristics (from self- and UV-curing to visible light-curing composites) [8]. (2) Late 1970'-mid 2000's with numerous filler modifications (from macro and micro-filled to hybrid and nano-filled) and (3) mid 2000's-mid 2010's with significant resin modifications (from methacrylate's to high molecular weight modified methacrylate's, siloxanes and self-adhesive composites) [9].

Evolution of Composite Resin in Dentistry

A field of dentistry which has experienced a more substantial evolution than that of dental materials would be difficult to imagine. Since materials were first introduced in dentistry more than 50 years ago, the structure of resin-based dental composites has grown dramatically. The application of composite resins was difficult at the beginning of the 2000s, as amalgam was the dominant choice for direct reconstruction. The aesthetics and mechanical properties continued to develop with the invention of nano-fills and nano-hybrids. Evolution and revolution of dental composites has been extensively discussed by the previous studies [10] and summarized in Figure 1. It can be concluded that proper adhesive contact management is critical for the consistent placement of many modern dental restorations. This necessitates an understanding of the materials used, the substrate to which they are attached, and a correct and exact clinical technique. Every clinician is responsible for learning about the exact adhesive being used, its peculiarities, advantages, and limitations, and how to maximize its effectiveness.

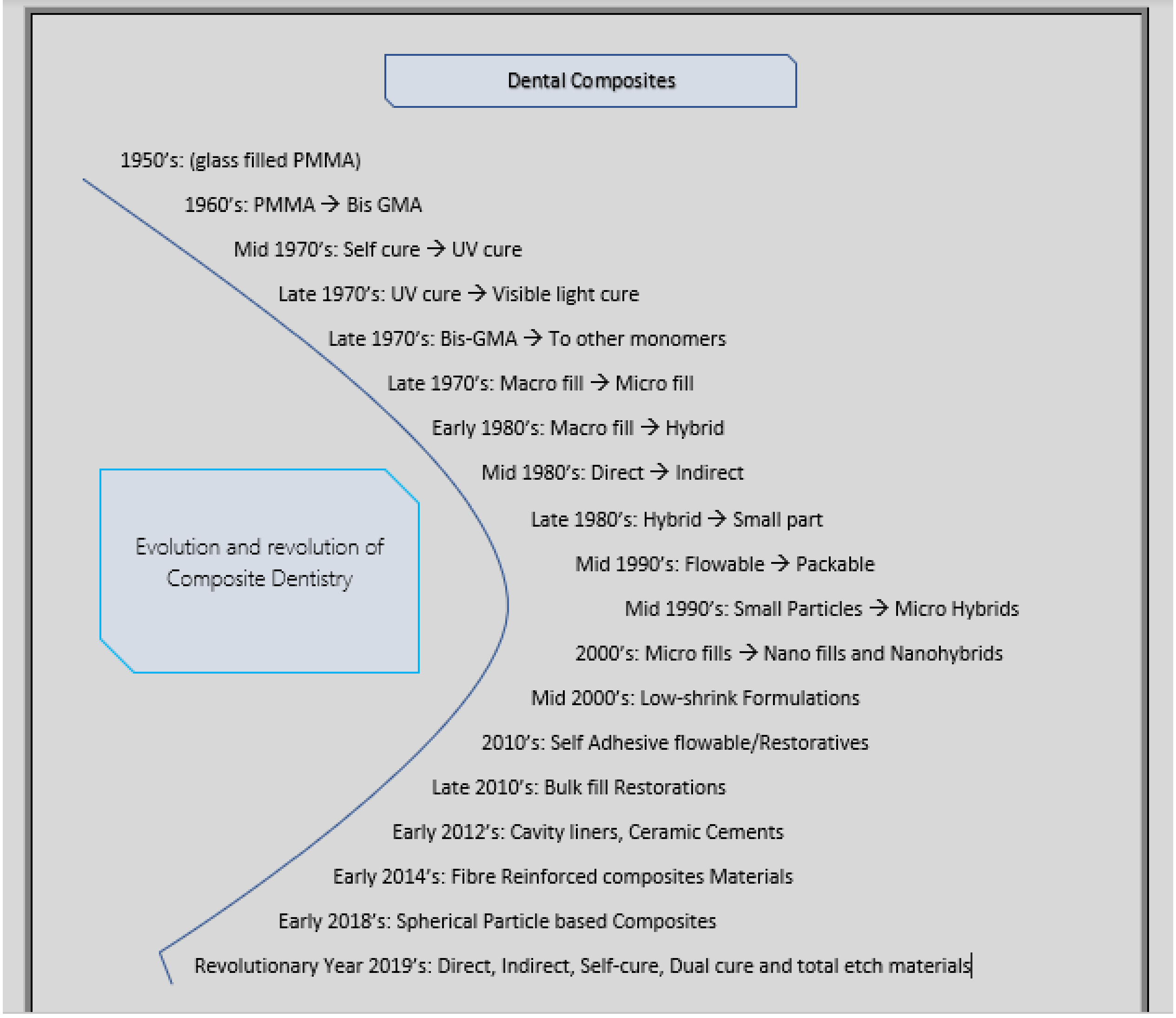

Figure 1: Evolution and Revolution in Composite Dentistry [11]

Classification of Dental Composite

There are various classifications of dental composite. It can be classified according to its organic resin matrix composition, inorganic filler type size and shape, based on method of curing, application, and consistency. Over the years, the classification of dental composite has advanced, but in general it has concentrated more on distribution of filler-size, quality of filler or composition. Most conventional resin composites correspond to a so-called "hybrid" group of "microfillers" or "nanofillers" containing only micro or nano-particles, respectively, and are currently widely marketed as "nanohybrids" [12]. The typical filler size used for the composite resin classification is as follows: macro-filled or traditional composites (10 to 100 μm), mid-fillers (1 to 10 μm), minifillers (0.1 to 1μm), microfillers (0.01 to 0.1 μm) and currently nanofillers (0.005 to 0.01 μm) [13].

Composition of Dental Composite

A composite material is a mixture of physical materials. Dental composites consist of three-dimensional combination of at least two chemically different materials with a totally separate interface separating the components. Dental composites consist of three chemically different materials: (I) organic matrix (organic phase), inorganic matrix (filler or disperse phase) and (iii) organosilane (coupling agent) bonding the organic resin to filler. The resin matrix consists mainly of bisphenol-aglycidyldimethacrylate (Bis-GMA) and UDMA (Urethane-dimethacrylate). As Bis-GMA is highly viscous on its own, it is mixed in different varieties with short-chain monomers such as TEGDMA (triethylenglycol-dimethacrylate). EGDMA (Ethylene glycol dimethylacrylate), HEMA (Hydroxyethylmethacrylate), Fillers (Quartz, Silica, Glasses, Zirconium dioxide and Tricalcium phosphate), coupling agents (Organosilanes, Titanates and Zirconates) activator (Benzoyl-peroxide) initiators (dimethyle-*p*-toludine), photosensitizers (camphoroquinone photosensitizers, dimethyle aminoethyl methacrylate DMAEMA), polymerization inhibitors (Butylated hydroxytoluene BHT and 4-Methoxy phenol), optical modifiers (Pigments- metal oxide, opacifiers like titanium dioxide, aluminium oxide) and ultra violer (UV) absorbers are contents of dental composites [14].

Different types of fillers in Composite Resins

Alumina

The use of composites as dental restoratives is gradually growing after several decades. Opportunities have recently emerged with the application of nanotechnology, with usage of newly available nano-particle formulations of different kinds [15]. Aluminum (Al2O3) or aluminum oxide occurs in nature as mineral component (Al2O3); diaspore (Al2O3·H2O); gibbsite (Al2O3·3H2O) [16]. Alumina's exceptional chemical properties have been used as insulation and high-temperature material in composites for many years. The stability and high elastic modulus of corundum made it one of the most widely used materials for high temperature applications. Various aluminum structures that can be obtained from heat treatments are of interest in composite materials [17].

Zirconia

Polymer dental materials are required to be long lasting, wear-resistant and biocompatible, and these requirements appear to be perfectly met by Zirconia [18] [19]. Adding Zirconia nano-particles to the resins was found to increase the strength due to its small size and homogeneous distribution [18]. Zirconia-based composites for restorative dentistry have been very versatile due to their superior fracture ability and toughness compared with other dental ceramic systems [20]. In recent decades, high quality composite materials incorporating silica and/or Zirconia nanofillers have become available with coloring systems and opacity choices that make it easier for a dentist to make tooth restorations so realistic that they are nearly impossible to detect by a neutral onlooker [21].

Glass fiber

New approaches have modified traditional treatment methods, as the use of novel oral materials gives improved performance [22]. The nature and composition of the resins and the design of the glass fiber reinforced structures in dental composites were studied in relation to their effect and properties, including mechanical, electrical, thermal, biocompatibility, vulnerability of the procedure, mode, and failures of the restorations on clinical use. Glass fiber reinforced dental materials are non-crystalline, uniform and fundamentally a three-dimensional network of loosely placed silica, oxygen and other atoms [23]. Examples of glass fiber used in dentistry are Alumino-borosilicate, corrosion-resistant E-glass, high-strength glass and glasses composed primarily of the oxides of magnesium, aluminum, and silicon. In restorative dentistry application, polycarbonate, polyurethane and acrylic base polymers such as poly-methyl-methacrylate (PMMA) and bisphenol-A glycidyl methacrylate (Bis-GMA) have primarily been strengthened with glass fibers and are usually treated with silane binding agents to reinforce chemical bonds between fiber and polymer matrix [24] [25].

Introduction to Fiber Reinforced Composite in Dental Applications

As a result of advanced treatment options focused on the development of new biomaterials, advancement of technology, and more effective treatment techniques, dental application is constantly developing with fiber-reinforced composites (FRCs) being a perfect example of this [26]. In many dental applications fiber-reinforced composites (FRCs) are category of non-metallic biomaterials that are increasing in popularity. Examples of non-metallic biomaterials are Resin composite restorative materials, Polyacid-modified resin composite (compomer), Glass ionomer (polyalkenoate) cement and Resin modified glass ionomer cement (RM-GIC).

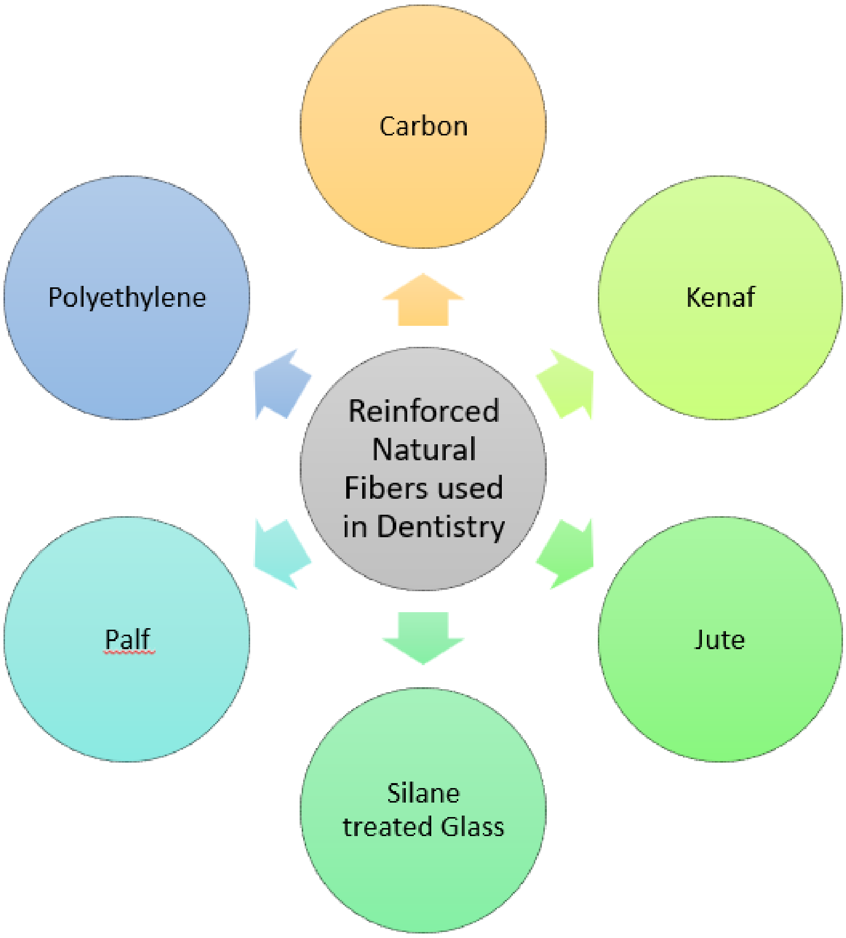

Figure 2: Cellulose/lignocellulose natural fibers mostly used in dental composites

The FRCs is a mixture of two materials in which one of the materials is in the form of fibers called the reinforced phase and is incorporated into the other material called matrix phase [27]. The guiding principles of FRCs need to be better understood with the development of new technologies nanofillers, resin matrices, fibers, adhesion protocols and application techniques which offer new areas of research both pre-clinically and clinically [28]. FRC has been introduced in dentistry and is being widely used in fixed-partial dentures, endodontic post system, fixed orthodontic retainers and splinting mobile teeth to delay tooth extraction in periodontology [29]. High use in aerospace, aeronautics, marine and automotive engineering has been observed for the mechanical properties of composite materials such as tensile modulus and flexural modulus, enhanced surface finish, durability of molded parts during manufacturing biodegradability and minimal health hazards[30] In contrast with other structural materials FRCs materials have high rigidity and strength per weight along with sufficient toughness [31]. Moreover, for higher tensile strength orientation of fibers at 90^0 shows good results as compared to 45^0 laminates. Critical evaluation of the available FRC material and recommendations for patient selection are of great importance for successful outcomes.

Properties of Fiber Reinforced Composite Resin

Over the past few decades, dentistry has rapidly evolved due to aesthetic properties and adhesion to tooth structure with good wear properties resins dominated amalgam [32]. FRCs are composite materials composed of three main components: the matrix (continuous phase), the fiber (dispersed phase), and the zone in between (interphase). When compared to other structural materials, FRC materials have a high stiffness and strength per weight, as well as appropriate toughness. There are several methods for increasing strength and other mechanical characteristics. One of the ways for incorporating fibers into dental composites demonstrates a significant increase in the characteristics of dental composites. Resin-based dental composite is one of those materials that undergoes several modifications and improvements [33, 34]. Glass fibers of various compositions are more widely used as restorative and prosthetic materials. FRCs based on kenaf, jute carbon, pineapple leaf fiber (PALF), polyaramid, polyethylene, and silane treated glass have been extensively researched as shown in figure 2. The mechanical and flexural properties of fiber reinforced composites (FRCs) structures have typically been found to be superior to those of non-reinforced in vitro composites [35]. According to a research, the modulus of elasticity for composite when one or more glass fiber groups were placed on the compression side of the sample, and toughness was enhanced significantly when one or more fiber groups were placed on the tension side of the sample [36]. At this stage, most of the dental composite was incorporated by the glass fibers or synthetic fibers. Natural fibers may be having potential to be used in dental composite. The kenaf fiber is shown to be good than other natural fibers [37]. The tensile strength of kenaf fiber, which is greater than other natural fibers (ranges from 80 to 4800 Mpa), has been shown to have strength of 930 MPa [38]. Previous research has proved the structural properties of dental composites can be enhanced by kenaf fiber [39].

Advantages and limitation of natural fibers application in dentistry

Natural fiber composite has some key advantages that make it more prominent nowadays. Due to its inherent properties of low weight, easy access, eco - friendliness, high strength and modulus, non-abrasiveness and low price compared to synthetic fibers, the applications of natural fiber reinforced composites are rapidly increasing. In addition to the hydrophilic nature of the fiber, the fiber content/amount of filler can also affect the properties of natural fiber reinforced composites[40]. The effect of fiber content on the properties of natural fiber-reinforced composites is therefore of particular importance. No or minimal laboratory work is needed for many FRC applications and frameworks can often be prepared at the chair side, directly in the oral cavity [41]. The other good aspect is the high aesthetics of these materials over metal-reinforced alternatives [42]. Research by Kurniawati on comparison of fracture toughness between nano hybrid composite and glass fiber reinforced composite revealed high tensile and shear stress values in the enamel and dentin of FRC as compared to nano hybrid dental composite. Moreover, it also suggested that the fracture resistance value of reinforced composite fiber was higher than a composite nanohybrid resin [43]. Finally, in patients allergic to nickel or other metals, the absence of metallic components in the FRC structure often encourages their use [44].

The major drawback of the FRC is the fiber and organic matrix interface [45]. This interface is compromised by intraoral hydrolysis and degradation, and failure can happen.

Future Perspective and recommendation

The extended use of these materials puts high demands on their properties and efficiency in a broad range of applications. Further progress of these materials is expected to include advance technology and further modifications in the properties of the materials as well as more applications of synthetic and natural fibers in the dental field.

Conclusion

With the advancement of composite technology, multiple fiber reinforced composite systems have been developed using various production processes to achieve enhanced material behaviors. Fiber-reinforced composite mainly derived from synthetic material has been discovered to be one of the most promising and effective types of dental composites, dominating many clinical applications. However, up to this stage, the use of natural fibers in dental applications is still lacking.

Competing Interests

The authors declare there are no competing interests.

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